Report No. RAC 357-2
(ARD 767-253)
12 October 1961

COMPILATION OF UNPUBLISHED MATERIALS INFORMATION

FIRST SEMI-ANNUAL REPORT

Contract AF33(616)-8084

April 1961 through September 1961

REPUBLIC AVIATION CORPORATION

Farmingdale, L.I., N.Y.

NOTICE

This document may not be reproduced or published in any form, in whole or in part, without prior approval of the Government. Since this is a progress report, the information herein is tentative and subject to changes, corrections and modifications.

FOREWORD

This progress report was prepared by the Republic Aviation Corporation, Farmingdale, New York, under USAF Contract AF33(616)-8084. The contract was initiated under Project No. 1(8-7381), Task No. 78812 "Compilation of Unpublished Materials Information on Company Sponsored Programs". This work was administrated under the direction of the Applications Laboratory, Materials Central, Directorate of Advanced Systems Technology, Aeronautical Systems Division, with Mr. F. Giese acting as project engineer.

This first semi annual progress report summarizes Republic's activities on current materials programs.

The materials programs reported in this compilation are the results of the efforts of many Republic personnel. Since a list of contributing personnel would be too cumbersome, only the departments responsible for the compilation and editing of the programs presented herein are noted. These were as follows: Manufacturing Research and Processes Department (Metallic, Nonmetallic, and Welding), Production Engineering Structures and Materials Test Section, Applied Research and Development Laboratories (Materials, Fluids, Guidance, and Electronics) and Technical Publications.

This program is being coordinated at Republic Aviation by Ronald W. McCaffrey of the Applied Research and Development Materials Laboratory (Applications Group).

ABSTRACT

Summaries are presented covering some of the many materials programs being conducted at the Republic Aviation Corporation. These programs are conducted under company sponsorship and in support of contractual committments. The summaries reflect the scope of Republic's non proprietary materials research on metallics and special purpose materials in the areas of fundamental research, applied research and development, engineering evaluation, processing development, and testing techniques. The programs described herein vary in complexity from a sophisticated study of fracture phenomena to a routine evaluation of vinyl tubing. Each summary describes the objective and current progress of the materials programs reported.

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont'd)

TABLE OF CONTENTS (Cont'd)

INTRODUCTION

The environmental and design requirements necessitated by current and advanced aerospace vehicles have created a myriad of divergent material requirements. In order to cope with the critical dependence of new vehicles on materials and to form a foundation for future materials programs, Materials Central has initiated a program to assemble timely resumes of current materials programs being conducted within the aerospace industry.

The materials programs included in this report have been selected from Republic's current non-proprietary laboratory programs. These programs are being conducted under company sponsorship or in support of contractual committments.

To assist the user of this report each resume has been classified as to the type of materials program (i.e. either fundamental research, applied research and development, engineering evaluation, processing development, or testing techniques) and material classification.

Type of Program: Fundamental Research

Material Classification: General Metallics

Descriptive Title: A Study of Fracture Phenomena

Objective: The program is a theoretical solid state investigation whose objective is to determine the interaction of dislocations resulting in microcrack formation when a crystalline solid is subjected to rapidly applied, high intensity stresses. (Contract AF29(601)-2869).

Abstract of Results and Conclusions: Results to date appear in a paper "The Dynamical Behavior of Dislocations in Anisotropic Media" which will be published shortly in The Physical Review. The dynamical behavior of uniformly moving dislocations in anisotropic media is discussed for those crystal systems for which the edge and screw components can be considered separately. It is found that screw dislocations behave normally at all velocities up to the limiting velocity. Edge dislocations, however, display an anomalous dynamical behavior. It appears that in general there is a range of velocities for which edge dislocations of like sign attract rather than repel one another. This anomalous behavior obviously may have importance in fracture phenomena since a coalescence of edge dislocations can lead to crack formation.

Type of Program: Fundamental Research

Material Classification: Plasma

Descriptive Title: Spectroscopic Study of Species Present in a Plasma Discharge

Objective: To identify chemical species in plasma discharges, qualitatively and quantitatively by means of spectroscopic analysis. (Contract AF49(638)-552).

Abstract of Results and Conclusions: Analytical techniques are being developed. Problems of eliminating electrical and magnetic noise have been largely overcome. Problems of calibration are being studied. At the present time the discharge spectrum is being studied as a junction of the discharge voltage and a position of the discharge area being viewed. The effects of pre-ionization and gas pressure also are being determined.

Type of Program: Applied Research and Development

Material Classification: Steel

Descriptive Title: Structures of Deformed Steel

Objective: 1. To determine the fundamental substructural characteristics of ausformed steel. 2. To apply the knowledge gained from the above to improve the mechanical properties of heat treatable steels.

Abstract of Results and Conclusions: The present study is focused on an attempt to interpret microstructural changes occurring in the various stages of ausforming or martensitic transformation. New metallographic techniques have been developed to reveal microstructures in greater detail by electron microscopy. Advanced electron microscopic replication, extraction, and transmission techniques were improved to yield highest possible resolution.

Based on these techniques, it has been shown that certain areas of interpretation of martensitic transformation and tempering of martensite have to be revised. The so-called subgrains in martensite as postulated by Cohen and co-workers are identified as "substructural elements" which basically participate or govern the martensitic transformation and are partially originated in the austenite. On early stages of tempering these "substructural elements" undergo changes before epsilon carbide precipitation takes place. Work is in progress to determine the nature of these substructural elements.

Type of Program: Applied Research and Development

Material Classification: Super Alloys

Descriptive Title: Determination of Causes of Cracking in Welding Age Hardenable High Temperature Alloys

Objective: 1. To determine the causes of hot cracking during welding of A-286 PH stainless, and of strain age cracking on components of Inconel X and Rene´41 during post-weld heat treatment. 2. To determine methods for alleviating the types of cracks described above. (Contract AF33(616)-7670) (WADC)

Abstract of Results and Conclusions: A-286 - Center line hot cracking can be alleviated when Inconel X, Inconel A, or Hastelloy W are used in place of A-286 for filler metal. A-286 possesses nil ductility from 2200°F up to its melting point, 2500°F. Grain boundary liquation occurs at 2350°F. Correlation has been noted between base metal HAZ (heat affected zone) cracking and grain size and a grain boundary precipitate. Fine grain size alleviates HAZ cracking.

Inconel X and Rene´41 - Aging contraction is a function of prior material history. Rene´41 contracts twice as much as Inconel X. Weld and HAZ material age hardens more slowly than 1950°F annealed base metal. Both materials exhibit a "ratchet" effect, i.e. the dimensional growth during annealing exceeds the dimensional shrinkage during aging. The one hour stress-rupture strength of annealed Inconel X at 1500°F is comparable to age hardened Inconel X but is substantially lower at 1200°F.

Type of Program: Applied Research and Development

Material Classification: Super Alloys

Descriptive Title: Microstructural Study of Weld-Cracking in Age Hardenable High Temperature Alloys

Objective: To determine the metallurgical factors responsible for the cracking of welded A-286 steel parts. (Contract AF33(616)-7670).

Abstract of Results and Conclusions: Specimens of A-286, annealed at various times and temperatures between 1950 and 2450°F, were metallographically examined. New techniques (electropolishing, special etching reagents, etc.) were developed for both light and electron microscopy. A large number of welded A-286 specimens and hot ductility test samples were examined and cracking correlated with observed structural changes.

It has been found that embrittlement of the A-286 alloy is caused by a pearl-like grain boundary precipitate, presumably a complex M_6C type carbide forming on slow cooling from temperatures between 2200 and 2000°F. Cracking of the base metal of a welded part occurs if the grain size of the base metal exceeds ASTM standard grain size No. 6.

Electron diffraction work is in progress to identify the embrittling grain boundary precipitate. A similar study is in progress for Inconel X and René 41.

Type of Program: Applied Research and Development

Material Classification: Super Alloys

Descriptive Title: Evaluation of Cracking in Welded Age Hardenable High Temperature Alloys

Objective: To determine the causes for basis metal and fusion line cracking based on the relationships of tensile strength and ductile-to-brittle transition temperature. (Contract AF33(616)-7670).

Abstract of Results and Conclusions: A series of mechanical tests were conducted on A286 at temperatures up to the melting temperature. The data was typical of hot shortness in an alloy due to phase and grain boundary relationships. Ductility increases with increasing temperature to a max. then drops sharply at some temperature substantially below the melting or coherency temperature. Tensile strength drops substantially at the nil-ductility transition temperature, but then shows a smooth decline to the melting point. The nil-ductility behavior temperature appears to be between 2100°F and 2200°F for the 3" x 3" billet and between 2200°F and 2250°F for the half-inch plate. These data are not consistent with the literature, where it is reported that A286 retains ductility to 2300°F. This difference in data is attributed to a rapid rate of heating. All of the specimens, being tested, reached temperature in less than 90 sec.

Similar testing is in progress on Inconel X and Rene 41.

Type of Program: Applied Research and Development

Material Classification: Super Alloys

Descriptive Title: Chemical Analysis of A-286, Inconel X, and Rene' 41

Objective: To analyze the subject alloys for trace elements generally not reported by the material supplier and to determine their concentration levels. (Contract AF33(616)-7670).

Abstract of Results and Conclusions: A-286, Inconel X, and Rene' 41 are being analyzed for traces of P, Si, Cu, Mg, Zr, B, O, and N.

Approximately 10-40 ppm of boron has been found in Inconel X and A-286.

Analytical procedures have been developed for determining small concentrations (0.01 to 0.1%) of zirconium in Inconel X. Using this analytical procedure approximately 0.01 to 0.05% zirconium has been found in Inconel X test specimens.

Magnesium has been found in Inconel X to the extent of 0.03%.

Analysis for oxygen and nitrogen are proceeding.

Type of Program: Applied Research and Development

Material Classification: Refractory Metals

Descriptive Title: High Temperature Fastener Development Program

Objective: To design, fabricate, and test structural mechanical fasteners having an efficient utilization capability in the temperature range 200 - 4500°F. (Contract AF33(616)-8104).

Abstract of Results and Conclusions: Four refractory alloys have been selected for preliminary investigation in the range of 2000 - 3000°F; TZM and TZC molybdenum alloys, F-48 and Cb74 columbium alloys. Two coating processes have also been chosen for the preliminary development phase of the program; the TAPCO columbium oxidation protective coatings and the Pfaudler molybdenum oxidation protective coatings. Preliminary redesign of conventional fasteners have been initiated to make them more amenable to manufacturing and coating application techniques.

Type of Program: Applied Research and Development

Material Classification: Refractory Metals

Descriptive Title: Evaluation of Electron Beam Melted Tungsten-Tantalum Alloy Buttons

Objective: To evaluate the physical properties of a series of tungsten-tantalum electron beam melted alloys.

Abstract of Results and Conclusions: Tungsten-tantalum powder compacts were melted twice in the electron beam furnace. Parameters such as vacuum pressure beam power, and beam dwell time were controlled. The following alloys were electron beam metled in addition to unalloyed tungsten and tantalum: 10W-90Ta, 30W-70Ta, 50W-50Ta, 70W-30Ta. Density measurements have agreed well with theoretical calculations. Specimens have been prepared for microstructural study and microhardness surveys. Chemical analyses are being conducted.

Type of Program: Applied Research and Development

Material Classification: Refractory Metals

Descriptive Title: Tungsten Alloy Sheet for Aircraft Structural Use

Objective: To produce tungsten alloy sheet of improved mechanical properties from vacuum melted ingots.

Abstract of Results and Conclusions: Double vacuum-melted ingots of 93W-7Mo were utilized to produce sheet-bar by direct forging methods and by extrusion techniques. Inspection methods, stress relieving, annealing cycles, and heating and forging techniques were determined. High purity, fine grain forgings were obtained with some evidence of flow and considerable modification and refinement of peripheral structures. The as-cast coarse structures at the billet center, however, were not refined, and intergranular failure occurred in the zone of coarse columnar grains. Attempts to produce sheet-bar by direct extrusion techniques, however, were successful. Yields were of the order of 85% and the extruded rounds obtained were press forged and subsequently rolled to sheet. Evaluation of the sheet is currently in progress.

This program was assisted by subcontracting appropriate portions to Ormet Metallurgical Corp., Ludish Company, and Universal-Cyclops Steel Corp.

Type of Program: Applied Research and Development

Material Classification: Refractory Metals

Descriptive Title: Evaluation of the Fabricability of Electron Beam Melted Tungsten Molybdenum Alloys

Objective: To determine the effect of purification and homogeneity on the fabricability of electron beam melted tungsten-molybdenum alloys.

Abstract of Results and Conclusions: This project has been conducted jointly by Republic Aviation and Universal Cyclops. Three tungsten alloy slabs - two 93W-7Mo, and one 93W-7Mo-Zr have been prepared by electron beam melting powder compacts. Each of the specimens were cut into thirds and examined microstructurally. Hardness measurements were determined for the as-cast material. Specimens were hot rolled in a vacuum at a pressure of 0.2 microns.

The results of these rolling experiments indicate that 93W-7Mo has some fabricability, however, the non-uniformity in thickness and the lack of homogeneity in microstructure induced failures before 50% reduction was obtained.

Type of Program: Applied Research and Development

Material Classification: Metals and Oxides

Descriptive Title: Thin Film Computer Logic Circuits

Objective: To develop thin film components such as diodes, tunnel diodes, resistors, and capacitors; and to incorporate these components into advanced computer logic circuits thereby advancing the state-of-the-art of small, compact, low-power computing systems.

Abstract of Results and Conclusions: The scope of the program includes the following:

(1) Vacuum and chemical deposition of thin films of various metals (e.g., titanium, aluminum, tantalum, platinum) and ferroelectrics (e.g., lead titanate-zirconate-stannate).

(2) Oxidation of metals to form insulating and semiconducting layers by anodization and thermal treatment.

(3) Incorporation of the thin film components fabricated in (1) and (2) into miniature computer logic circuits.

Progress to date has included the development of reliable thin film diodes, resistors, and capacitors. Work is continuing on the inclusion of these components into computer logic circuits.

Type of Program: Applied Research and Development

Material Classification: Seals and Fluids

Descriptive Title: Pneumatic Seal Development Program

Objective: To develop elastomeric seals for 4000 psi airborne pneumatic systems operating in the temperature range of -65°F to +275°F. In addition, a suitable elastomer grease and compressor lubricant are to be selected from available candidates. Gland design is to be optimized. Seals in the 5/8-inch and 1 3/4-inch piston rod sizes are ultimately to be tested to the following profile:

1. Air age at 225°F and 275°F, zero psi., for 36 hours each.
2. Cold soak 16 hours at -65°F, zero psi.
3. Perform 15,000 cycles at 225°F and 15,000 cycles at 275°F, 0-4000 psi, 4-inch stroke, 35 cpm.
4. Repeat cold soak, item 2.
5. Perform 10,000 cycles at 225°F and 10,000 cycles at 275°F, as above.

Leakage at high and low pressure is measured periodically at all operating temperatures. (Contract AF33(616)-7561).

Abstract of Results and Conclusions: Elastomers screened were buna N, silicone, polyurethane Viton, neoprene, and resin-cured butyl. All but Viton and butyl exhibited inferior heat and/or decompression resistance. Viton was rejected for known poor low temperature performance. Seals were developed with butyl 0-rings, loaded Teflon backups, and silicone grease. Compression set of 0-rings was the most difficult condition to overcome. Decompression fatigue was greatly reduced by special multiple backups between the pressure source and the 0-ring, which acted as a buffer to reduce rapid pressure changes at the sealing surface. Compressor lube selection appears unfeasible unless supported by extensive testing beyond the scope of the program.

Work is still in progress and will be reported in a final document to be forwarded to WADD by the end of 1961.

Type of Program: Applied Research and Development

Material Classification: Seals and Fluids

Descriptive Title: Design and Development of a 1000°F Hydraulic System

Objective: To develop a 1000°F, 4000 psi hydraulic system. (Contract AF33(616)-7454).

Abstract of Results and Conclusions: A fluid selected in an earlier phase of this program was further tested and analyzed to determine the effects of temperature, operation, and nuclear radiation. State-of-the-art surveillance of fluids has been maintained. Fluid properties required for system design and evaluation have been determined.

Seals for dynamic application were also tested. These included the Bar X rod seal and the Precision piston rings. These rings were used for both rod and piston head seals. Additional piston head seals included C. L. Cook piston rings and Graphitar piston rings. Two RAC proprietary designs using Armour Rresarch Foundation metal fiber composites were also tested as rod seals. The same fiber metal composites were used as crush gaskets in static seal application. Also used for static application was the Instra-Tech seal and silver plated metallic 0-rings.

Results of these tests are being evaluated for design application.

Type of Program: Applied Research and Development

Material Classification: Seals and Fluids

Descriptive Title: Gas Chromatographic Analysis of High Temperature Hydraulic Fluid

Objective: To identify, by gas chromatographic analysis, the products of degradation limiting the performance of high temperature fluids. (Contract AF33(616)-7454).

Abstract of Results and Conclusions: Used and unused bis (phenoxyphenyl) ether hydraulic fluids have been analyzed for the major components of the fluid and trace impurities. The degradation of the fluid has been studied to determine the effect of temperature (700° - 1000°F), pressure (300 - 500 psi), and metallic surfaces. Experiments are in progress to identify the pyrolysis products, and evaluate mixtures of different high temperature fluids. Preliminary calculations have been performed for decomposition rates of major components.

Type of Program: Applied Research and Development

Material Classification: Coatings

Descriptive Title: Refractory Coatings Program

Objective: Evaluation of oxidation resistant coatings for refractory metals

Abstract of Results and Conclusions: Several commercial experimental protective coating are under evaluation for alloys of molybdenum columbium, tantalum, and tungsten. Some of the coatings that have been under evaluation include Chromalloy's W-2, Pfaudler's PRF-6, Sylcor's #34S, and American Machine and Foundry's AMF Kote #4. Preliminary screening tests have been conducted on small rectangular tabs exposed to a mildly dynamic oxidizing evnironment between 2000° and 3000°F. Other testing emphasizes the evaluation of more complex shapes, assembled by welding or mechanical methods. These specimens are being evaluated under thermal exposure and load. Metallographic techniques have been employed to examine the uniformity of coating thickness, adherence, and diffusion.

Type of Program: Engineering Evaluation

Material Classification: Metallics General

Descriptive Title: Evaluation of Electric Discharge Machined Holes Versus Twist Drilled Holes in Inconel X, C110M, and Rene´41 Sheet

Objective: To determine if Electric Discharge Machined holes in structural sheet alloys could be used for riveted attachments "as machined".

Abstract of Results and Conclusions: Room temperature static tensile and tension-tension fatigue tests were performed on specimens with both Electric Discharge Machined (EDM) and twist drill holes, for the C110M titanium and Inconel X sheet. Test specimens were 1" wide and contained 5/32" holes.

For Rene´41 sheet, tests on both types of holes were run on riveted joints. These joint tests included static tension at room temperature and 1300°F, and tension-tension fatigue at room temperature.

The tests, though not entirely completed, indicate that EDM holes can be used in Inconel X and Rene´41 with no additional treatment after the machining. The results indicate that the process is not satisfactory for the titanium sheet.

The testing should be completed by December 1, 1961.

Type of Program: Engineering Evaluation

Material Classification: Aluminum

Descriptive Title: Fatigue Tests of Riveted and Spot Welded 7075-T6 Aluminum Joints

Objective: To determine fatigue allowables of aluminum protruding head rivets in clad 7075-T6 sheet, aluminum flush-head rivets in machine countersunk or dimpled clad 7075-T6 sheet, and resistance spot welded clad 7075-T6 sheet.

Abstract of Results and Conclusions: The program covers sheet gauges from .050 through .125 and rivet sizes of 5/32, 3/16, and 1/4". The spotwelded joint configurations cover only the .050 and .072" gage material, while the spotweld efficiency specimens cover the .063-.100 range. Specimen configuration is large, 4.5" across the test section with five spots or five rivets. Testing is in progress and should be completed by January 1, 1962.

Type of Program: Engineering Evaluation

Material Classification: Aluminum

Descriptive Title: Corrosion Protection of Riveted Joints

Objective: To evaluate various corrosion protection systems for use with permanently attached fasteners.

Abstract of Results and Conclusions: A series of tests were run on 18 fastener insulations, of the paint and sealant variety. These tests included salt spray and humidity exposure followed by vibration and tensile checks. Panels were of clad 7075 aluminum, with 7075 angles and extrusions riveted on with 24S and 17S aluminum flush and brazier head rivets. Visual examination showed no evidence of corrosion in specimens checked thus far. The program should be completed shortly.

Type of Program: Engineering Evaluation

Material Classification: Aluminum

Descriptive Title: Cause and Remedy of Low Leak Rate Defects in Fusion Welded 6061, 5052 Aluminum Alloy Fuel Line

Objective: To evaluate and compare welding techniques and filler rod types to determine the optimum combinations which will elimate low leak rate defects in fusion welded fuel lines of 6061 and 5052 aluminum.

Abstract of Results and Conclusions: A joint, consisting of a 2" diameter tube with a fishmouth tee connection to a 2 1/2" diameter main tube, was selected for evaluation because of a history of leakage on production parts. The program included the following studies:

1) Oxy-acetylene vs. TIG welding
2) Effect of filler rods 4043, 5536, 718
3) Effect of tack locations

Low leak rates were caused by hot tearing under conditions of restraint. Defects can be eliminated by proper welding and tacking techniques and/or filler rod with appropriate characteristics in the liquidus-solidus temperature range.

Type of Program: Engineering Evaluation

Material Classification: Titanium

Descriptive Title: Mechanical properties of B120VCA Titanium Alloy Sheet at Elevated Temperature

Objective: To determine the elevated temperature properties. thermal stability, and notch sensitivity characteristics of B120VCA aged material.

Abstract of Results and Conclusions: Elevated temperature strength levels have been established at the temperatures of 400, 500, 600, 700, 800, and 850°F. Thermal stability has been evaluated for heat treated thin gage (.015") material after short time (30 minutes) and longer time (10 hours, 100 hours) exposure at 500, 600, 700, and 800°F. Notch sensitivity was evaluated for .015 sheet material for K_t's of 4.0, 6.0, and 10.0.

Evaluation of joining techniques is now in progress. Methods of joining evaluation include fusion welding, spot welding, and brazing.

Type of Program: Engineering Evaluation

Material Classification: Nickel

Descriptive Title: Evaluation of Mechanical Attachments in Rene' 41 and Inconel X Sheet at 900°F - 1800°F.

Objective: To determine joint strengths in short time tension and under creep-rupture conditions for use in high temperature sheet structures.

Abstract of Results and Conclusions: A series of tests, on 1/8", 5/32", and 3/16" Inconel rivets, 3/16" Inconel X rivets, and 3/16" Hy-Lok fasteners were performed on various .025" and .050" Inconel X and Rene' 41 sheet combinations. These tests were accomplished over a temperature range of 900° - 1600°F for the Inconel X sheet combinations and 900° - 1800°F for the Rene' 41 sheet combinations. Short time (5 min. at temperature) tensile tests and tensile creep-rupture tests (up to 100 hrs.) were performed.

The short time tests showed acceptable strength for all combinations, while the long time tests showed the Inconel rivets to be inefficient above 900°F.

Testing has been completed and final data summations should be completed by December 31, 1961.

Type of Program: Engineering Evaluation

Material Classification: Plastics

Descriptive Title: Investigation of Acrylonitrile-Butadiene-Styrene (Royalite) Material for Non-Structural Aircraft Components

Objective: To evaluate the suitability of "Royalite" material for use in non-structural aircraft parts by determining impact strengths.

Abstract of Results and Conclusions: Charpy impact tests were conducted to determine the suitability of 1/8 inch thick Royalite in the temperature range of -70°F to +70°F. Previous studies have shown this type of material to be readily formable, low in cost, and of adequate intrinsic physical properties to function for the intended purpose. This test has shown that the low temperature impact properties of Royalite, which were not published, are sufficiently high to permit fabrication of satisfactory non-structural aircraft components.

Type of Program: Engineering Evaluation

Material Classification: Plastic

Descriptive Title: Abrasion Test of Electrical Tubing, Flexible Vinyl Insulation Sleeving, MIL-I-7444

Objective: To demonstrate that vinyl tubing would be satisfactory as a chafing protection in certain electrical sleeving application.

Abstract of Results and Conclusions: Testing was accomplished on a Taber Abraser. The vinyl material yielded an average weight loss of 0.15 gms after 3000 cycles using an H-22 wheel. Based on a comparison with neoprene rubber (MiL-R-6855 Class II, Grade 40), which has a published weight loss value of 5.9 gms when tested under similar conditions, the vinyl tubing is considered satisfactory.

Type of Program: Engineering Evaluation

Material Classification: Plastics

Descriptive Title: Investigation of Out-Gassing of Isocyanate Foam Material

Objective: To determine the out-gassing characteristics of encapsulated and base isocyanate foams.

Abstract of Results and Conclusions: The samples evaluated for out-gassing were bare polyester-urethane foam(Lock foam) block and the same type of block encapsulated in an epoxy-fiberglass laminate. The density of the foam used was 6.0 #/ft^3. Prior to testing and encapsulating, each of the samples was thoroughly dried in a desiccator. The blocks were exposed to a positive pressure of 1×10^{-3} mm of Hg for a minimum of 8 hours at 73 ±5°F. Out-gassing was determined by weight change. The bare foam block lost 2.1% of its weight compared to 0.02% weight loss for the encapsulated block.

Type of Program: Engineering Evaluation

Material Classification: Sandwich

Descriptive Title: Mechanical Properties of Bonded Aluminum Honeycomb at Elevated Temperatures

Objective: To determine various mechanical properties of bonded aluminum honeycomb specimens and to measure retention of these properties at elevated test temperatures and, also, after varying specified temperature, time, and load exposure conditions.

Abstract of Results and Conclusions: After a preliminary test program involving three adhesive systems (Bloomingdale Rubber Company - HT424/HT427F; Rubber and Asbestos Corporation BV131A/CL59E; Adhesive Engineering Company, Aerobond 430/P413), was run for screening purposes, HT424/HT427F was selected for further investigation.

New specimens for testing were fabricated using 5052H39 core material, X2020T6 sheet material, and HT 424 adhesive. These specimens were tested and values obtained for lap shear, adhesive flatwise tensile, peel tests, core lap shear, and short and long beam flexures. Also included was a joint and fastener series of tests including plate shear, bending, compression and tension, tensile creep fatigue, and fitting shear. Test temperatures and exposure temperatures generally included a range from room temperature to 400°F. Exposure times went up to 1000 hours for some tests. In certain cases, testing and exposures were accomplished at temperatures as high as 600°F and as low as minus 67°.

Data obtained is presently being evaluated and planned follow-on phases for this program will investigate simple time-temperature-load variations, component testing, and complex time-temperature-load variations.

Type of Program: Engineering Evaluation

Material Classification: Seals, Fluids, and Sealants

Descriptive Title: Metallic Boss Seal Evaluation and Test Program

Objective: To evaluate performance capabilities of USAF X57A800 - Boss Type Metallic Seal, USAF X59C6184 - Boss Type Metallic Gasket, and NAVAN VD261 - Natorq Static Seal when installed on fittings and bosses of various material combinations. (Contract AF33(616)-7297).

Abstract of Results and Conclusions: The NAVAN and X59C6184 seals were available in aluminum and stainless steel; the X57800 was available in stainless steel only. The working pressure and temperature for aluminum assemblies was 2,000 psi and 400°F, respectively. The working pressure for carbon steel, stainless steel, and titanium assemblies was 4000 psi, with operating temperatures of 800°F for titanium and stainless assemblies and 400°F for carbon steel assemblies. The seals, ranging in size from 3/16 inch to 1 inch, were tested for leakage after exposure to room temperature and low temperature (-320°F) pressurization; thermal cycling (between room temperature and maximum temperature); vibration (300 to 500 cps at 20-g for six hours each at room temperature and maximum temperature); impulse testing (200,000 hydraulic impulses at 150% of the working pressure, 50% of them at maximum temperature); and repeated assembly and dis-assembly.

Tests results have shown that:

(1) Of the three seal configurations tested, the USAF X59C6184 seal provided the most reliable performance.

(2) Sealing efficiency generally decreased with increasing seal diameter.

(3) Seals were reliable when sealing helium at room temperature but not at -320°F.

(4) Vibration tests did not affect sealing capabilities.

(5) Impulse tests were the most severe of all five tests.

The program has been completed, and a draft of the final report has been recently forwarded to WADD. A progress report was delivered before the SAE at Detroit on April 20, 1961.

Type of Program: Engineering Evaluation

Material Classification: Seals, Fluids,and Sealants

Descriptive Title: High Temperature Hydraulic Evaluation Program

Objective: To evaluate dynamic and static seals, fluids, and components in an environment ranging from -65°F to +600°F at 3000 psi. (Contract AF33(616)-6066).

Abstract of Results and Conclusions: 0-rings molded from Viton and Fluorel (both fluorinated hydrocarbons) and Rulon (reinforced Teflon) were selected as the most suitable elastomers for evaluation. Back-up rings were fabricated from Duroid D5613, Rulon, and several other types of reinforced Teflon material. Standard glands and back-up rings were modified to extend service life of the seals. Metallic seals for dynamic and static applications were also evaluated. Mineral oils, both undewaxed and deep dewaxed types, were selected as test fluids. The latter was used during low temperature testing and component testings. Rod seals ranging in size from 1/2 to 2 inch rod diameter were generally subjected to short-stroke (1/4" stroke, 250 cpm) mechanical cycling at constant pressure (3000 psi), and long-stroke (2" stroke, 40 cpm) mechanical cycling with impulsing pressure (50 - 3000 psi). Thermal cycling (+ 70°F to 600°F and back to +70°F) was performed concurrent with mechanical actuation. Static seals were tested with continuous pressure impulsing (50 - 3000 psi, 40 impulses per min.) while undergoing thermal cycling.

Results have shown that -

(1) Service of elastomeric seals under these conditions depends primarily on the resistance of the material to loss of desirable mechanical properties.

(2) Viton 0-rings, compound nos. XWAV-5 and 1700-90, show the most promise in dynamic and static applications.

(3) Back-up rings of Duroid 5613 material were consistently reliable in dynamic sealing applications.

(4) Life of metallic seals in dynamic applications are limited due to their high shape rigidity resulting in the inability of the seal to conform to surface irregularities

(5) The deep dewaxed mineral oil is a promising fluid for 600°F operation.

The program has been completed, and a final report forwarded to WADD on March 31, 1961. Release of this report will be initiated by WADD under TR60-896.

Type of Program: Engineering Evaluation

Material Classification: Seals, Fluids,and Sealants

Descriptive Title: Integral Fuel Tank Sealants

Objective: This study was initiated to evaluate sealants for integral fuel tanks for operating temperatures ranging from -67° to 400°F.

Abstract of Results and Conclusions: A screening test of several basic sealants such as silicones, Vitons, and polysulfides was conducted to determine the suitability of the various sealants for application in an integral fuel tank for operation at 400°F. This screening test basically consisted of exposing the sealants for seven days after a pre-exposure of 180°F in jet reference fluid. Speciments that passed the exposure tests were then subjected to -65°F exposure and flexed at this temperature to determine the flexibility of the sealant. In addition to the above, peel strength tests were conducted on the various sealants after exposure to 400°F for seven days after a pre-exposure of 180°F in jet reference fluid. Of all the sealants screened, only the Viton base compounds passed all of the screening tests. Further evaluation of the Viton base sealant system is in progress and is being conducted in accordance with Specification MIL-S-8802B with modifications as suggested by AIA Specification ARTC-13. Preliminary results of this program indicate that Products Research Corporation's sealant PR1730 (a Viton A base compound) is satisfactory for integral fuel tank sealing at the test exposure temperatures.

Sealability of characteristics PR1730 sealant under dynamic loading will be evaluated by employing a "puffer box" test fixture. This series of tests is in progress. Results will be reported at the completion of the test program.

Type of Program: Engineering Evaluation

Material Classification: Bearings

Descriptive Title: Preliminary Evaluation of Self-Lubricating Materials for Use in Sliding Block Applications at High Loads

Objective: The object of the program was to evaluate a specific design use of sliding bearings on an elastic support. A secondary objective was to obtain material friction coefficients (static and moving) as well as wear rates.

Abstract of Results and Conclusions: A preliminary bearing block design was used with four different self-lubricating material faces: Du material, Progreg, Everlube, and Fabroid. Fabroid proved to be the most durable material with the coefficient of friction varying from 0.083 to 0.151 at a PV value of 43000 psi x fpm. Difficulties in conjunction with mechanical design led to premature local wearing of the bearing face thereby leaving the question of wear rates unanswered. However, tests are in progress utilizing a modified design from which more conclusive data on wear rates should be determined.

Type of Program: Engineering Evaluation

Material Classification: Miscellaneous Special Purpose Materials

Descriptive Title: Wave Guide Window Material Tests

Objectives: To determine the dielectric constants and attenuation characteristics of high temperature radome materials.

Abstract of Results and Conclusions: The materials being evaluated include: Duroid 5650 end grain and flat grain (teflon reinforced with ceramic fibers), foamed Glas-Roc (expanded silica), fused silica 7940M, Pyroceram 9606, and a Republic proprietary composition (fiberous modified silicone).

Dielectric constants and attenuation characteristics have been determined at room temperature using a reflectometer and slotted line. The testing has been conducted in the frequency range of 8 to 10.5 kmc. Of the materials tested, the foamed Glas-Roc has exhibited the lowest dielectric constant and the lowest degree of attenuation.

Additional testing in the 1000°F to 2000°F temperature range is scheduled for the near future.

Type of Program: Engineering Evaluation

Material Classification: Miscellaneous Special Purpose Materials

Descriptive Title: Chemical Descaling of Rene' 41 Sheet Material

Objective: To determine whether a chemical descaling method can be substituted for costly vapor blast operation without a resulting degradation in mechanical properties.

Abstract of Results and Conclusions: Four chemical descaling methods, referenced below, were compared with the vapor blast descaling method and scaled controls. Results of room temperature and 1400°F tensile tests, and room temperature flexure fatigue tests indicate that these chemical descaling methods are inferior to the vapor blast method. The chemical descaling methods caused a 10% reduction in strength and almost a complete loss of ductility.

Descaling methods used were:

(1) As per Boeing Airplane Company, Aerospace Division Mfg. Report 2-17059.

(2) As per North American Aviation Inc. Process Specs. LA0110-006 and LB0225-101.

(3) As per Turco Products, Inc. Technical Data Bulletin No. 35.

(4) Virgo descaling bath, operating at 787°F followed by immersion in three baths in the following sequence:
   a) 10% muriatic acid
   b) 10% intric acid
   c) 10% nitric acid plus hydrofluric acid

Type of Program: Processing Development

Material Classification: Metallics - General

Descriptive Title: Correlation of Surface Preparation Relative to Mechanical Properties of Thin, High Strength, Low Ductility Materials

Objective: To evaluate the effect of specimen surface preparation on mechanical properties in order to establish preparation techniques for optimum test results.

Abstract of Results and Conclusions: The scope of this program will include testing of typical materials representative of the various types of high strength materials such as stainless steels, titanium alloys, nickel base alloys, etc. Thicknesses below .015" are being investigated since the effect of surface preparation becomes most pronounced as gage decreases. Both face and edge preparation are being investigated.

Initial tests have been conducted on .010" gage 17-7PH stainless steel, evaluating preparation techniques such as blanking, machining, surface protection during heat treat, effect of removing edge material to various depths, and descaling techniques such as pickling, vapor blast, belt or hand sanding, abrasive polishing, etc. Further testing is commencing using thinner gages to determine the influence of material thickness on the effect of various treatments. Effect of strain rate during testing will also be investigated.

Specimens are currently being prepared for tests to be conducted with titanium.

Type of Program: Processing Development

Material Classification: Metallics - General

Descriptive Title: Study of Electrical Discharge Phenomena as Related to Metal Forming

Objective: To investigate and evaluate the significance of the basic parameters involved in the forming of sheet metal by means of underwater pressure waves produced by underwater capacitor discharge sparks. (Contract NAS 8-890)

Abstract of Results and Conclusions: This program is being conducted at energy levels up to 39,000 joules with the use of a standard 10" diameter dish shape as a standard configuration for all tests. Several aluminum alloys in "O" and T condition and 1/16" to 1/4" thickness shall be formed. The rate of energy input to the underwater spark as well as the magnitude of energy are being controlled by circuit parameters and electrode configurations. The effect of energy and energy rate (power) are being observed in terms of (1) the expansion of the gaseous products produced by the underwater spark, (2) the profile of pressure time curves obtained by piezoelectric pressure transducers, and (3) by the extent and rate of metal deformation as observed by high speed photography. The efficiency of the process at various operating levels will be determined.

Type of Program: Processing Development

Material Classification: Metallics - General

Descriptive Title: Capacitor Discharge Metal Forming

Objective: To determine the formability of various yield strength metals in underwater capacitor discharge forming and to develop a process for forming rocket cases and missile domes. (AF33(600)-42920).

Abstract of Results and Conclusions: A state of the art survey conducted in Phase I indicated that several organizations have satisfactorily formed small tubular parts and dished sheet parts by capacitor discharge forming. Very little work has been done in the area of developing the process by investigation of process parameters.

The current Phase II work is concerned with the construction of a 155,000 joule capacitor bank to provide the energy required for the forming of larger parts such as 24, 48, and 120 inch diameters.

Phase III will be concerned with the influence of process parameters upon the efficiency of forming 24" diameter dome specimens in 24 ST aluminum, steel, 6A1 4V titanium alloy, Rene'41, and columbium. In addition, the feasibility of expanding heavy wall 10" diameter steel cylinders will be investigated.

In Phase IV configurations of current aerospace vehicle interest will be selected to determine the capability or limitations of the capacitor discharge forming equipment.

Several parts in two selected configurations will be formed to establish reproducibility, tolerance, and cost.

This page intentionally left blank.

Type of Program: Processing Development

Material Classification: Aluminum

Descriptive Title: Hot Preforming of Aluminum Alloys

Objective: To develop hot forming techniques which will permit the replacement of machined aluminum alloy parts with hot formed parts using sheet metal or plate.

Abstract of Results and Conclusions: Formability tests have been conducted on several heat treatable alloys to determine optimum forming temperatures and forming limitations. Results indicate that optimum formability is achieved in the 400°F to 840°F range, with little advantage to be gained below 400°F.

Several actual production parts have been produced successfully using a number of tooling materials and techniques. In some instances, forming of the part includes coining of local areas to achieve a reduced cross section previously produced by machining.

Mechanical property tests conducted with specimens cut from hot formed parts indicate that properties of the material are not adversely effected. In fact, fatigue life is improved, indicating possible weight savings if the hot forming process is used.

Tests have been conducted to determine minimum solution treat time at temperature required to produce satisfactory mechanical and metallurgical properties Specimens of .160" gage 7075 aluminum alloy exhibited satisfactory properties in all respects after time-at-solution-temperature as short as one minute. Results of this test suggest the possibility of combining hot forming and solution treatment by forming at the solution treating temperature.

An aluminum hot forming specification has been prepared, based upon principles and techniques established during the course of this program. Current effort is directed toward incorporating the hot forming technique as a standard production process at Republic Aviation Corporation.

Type of Program: Processing Development

Material Classification: Aluminum

Descriptive Title: Preliminary Investigation of High Frequency Welding

Objective: To evaluate and compare the advantages of high frequency welding versus other welding processes.

Abstracts of Results and Conclusions: Aluminum alloy 2024-T3 tubing was chosen for this evaluation. Preparation of the longitudinal butt joint for welding after machine cutting one side of the tubing holding straightness and close tolerance was mandatory.

Comparison evaluation of high frequency welding and machine TIG welding joint efficiencies were made by hydraulic pressure bursting the tubing, and computing the results.

The conclusions are as follows:

1. Literature surveys indicate advantages to be gained by high frequency welding are in increased production rates, in material cost savings, and in metallurgical benefits derived from the process.
2. Data accumulated in this investigation indicate that the high frequency welding process has an increased joint efficiency in aluminum alloy 2024-T3 tubing of 13% over that of automatic machine TIG weldments.
3. Metallographic studies made of the aluminum alloy 2024-T3 tubing high frequency welded joints indicate feasibility of rapidly producing weldments with little or no heat-affected zones.
4. Die configuration on the high frequency welding equipment is limited to making flat weld specimens having an overall width dimension of only one inch, thereby limiting mechanical data.
5. Material preparation in maintaining dimensional tolerances in width of specimens for butt joint high frequency welding poses a problem.

Type of Program: Processing Development

Material Classification: Magnesium

Descriptive Title: Forming Investigation of HK31 Magnesium

Objective: To determine the fabricating characteristics of HK31 magnesium alloy.

Abstract of Results and Conclusions: HK31 Magnesium has been previously investigated for general formability characteristics. The current studies are concerned with specialized problems.

One problem currently under investigation is the dimpling of composite double skins consisting of HK31-H24 and AZ31B. This operation is difficult because of the large difference between the optimum dimpling temperatures for the two alloys (350°F for AZ31B, 650°F for HK31). At 350°F the HK31 cracks, while at 650°F the AX31B is too plastic, resulting in excessive deformation. Various combinations of temperature, pressure, and tool configuration have been investigated. Best results thus far have been achieved by using double action on both punch and die, at 650°F. However, sheet separation caused by excessive distortion of the AZ31 is still a problem.

Another project currently in work is the manufacture of a typical thermal protection structure consisting of a columbium or Rene' 41 outer skin mounted on an HK31 magnesium frame. Suitable insulating materials are placed between the skin and frame to maintain frame temperatures compatible with magnesium.

Type of Program: Processing Development

Material Classification: Titanium

Descriptive Title: Improved Methods for the Production of Titanium Alloy Extrusions

Objective: To produce thin structural extrusions in high strength titanium alloys. (Contract AF33(600)-34098).

Abstract of Results and Conclusions: With the use of molten glass as a lubricant for extrusion, 20 foot lengths of 7A1-4MO titanium alloy have been produced in 20 to 25 foot lengths. Consistently smooth extrusion surface has been obtained throughout the extruded length. The glass lubricant eliminates or reduces die wear to a negligible degree by covering the entire extrusion with a thin (.001") coating of molten glass. In the completed work phases, (I to III), extrusions have been produced in 3/32" x 1" angles and 1/8" x 2" tee shapes. The program is currently in Phase IV in which 1/6" x 2" extrusions will be produced by extrusion and warm (1200°F) drawing or by a combination of these processes. Extrusions will be produced in 7A1-4MO, 6A1-4V, and 4A1-3MO-1V titanium alloys.

The as-extruded room temperature tensile strength of the 7 Al - 4 Mo alloy is approximately 170,000 psi ultimate, 150,000 psi yield, with 12% elongation. Heat treatment increases the strength to 190,000 psi ultimate, 175,000 psi yield, and reduces elongation to 2%. The creep strength of 7 Al - 4 Mo extrusions is less than .5% with 500 hour, 800°F exposure, at 70,000 psi.

Type of Program: Processing Development

Material Classification: Titanium

Descriptive Title: Fabrication Program - B120VCA Titanium

Objective: Familiarization with manufacturing techniques required to produce advanced structures utilizing B120VCA Titanium.

Abstract of Results and Conclusions: Emphasis has been placed on the investigation of thermal processing during the course of this program. After extensive testing, it was found that the optimum combination of strength and elongation could best be achieved through the use of a duplex age; 900°F for 66 hours followed by a flash anneal at 1050°F for 5 minutes. Studies also have been conducted to investigate thermal stability and dimensional control.

The material used to date was approximately two years old; additional heat treat studies will be conducted with current material to investigate the necessity for duplex aging.

Elemental shapes such as angles and channels have been fabricated for tests in bending and compression. A number of honeycomb sandwich panels are being manufactured for elevated temperature testing. Detail parts for these panels have been completed and are now ready for brazing assembly.

Single and double skin welded corrugated panels have been fabricated for testing in bending and compression at elevated temperature.

Type of Program: Processing Development

Material Classification: Titanium

Descriptive Title: Fusion Welding of B120VCA Titanium and Response of Weldments to Heat Treatment

Objective: 1. To develop a fusion welding technique for the production of continuous welds in thin gage material (.015 - .040).

2. To investigate the response of weldments to various heat treat cycles and develop a heat treatment which will produce compatible optimum properties in both weldment and base metal.

Abstract of Results and Conclusions: A satisfactory schedule for the mechanized welding of seam butt joints in .015 and .040 gage sheet material was established. Joint preparation consisting of draw-filed edges and mechanical cleaning of adjacent area was sufficient to produce weldments of acceptable x-ray quality with a minimal occurrence of porosity. Filler wire of similar composition to base metal was used on the .040 gage material. No filler wire was required for .015 gage material.

The investigation of heat treat cycles was exploratory in scope and very limited with respect to number of specimens per condition. Evaluation was restricted to room temperature tensile testing. In general, four types of heat treat cycles were considered: single stage cycles - age at 900°F for 50 hours; two stage cycles - age at 900°F for 50 hours followed by flash annealing at 1050°F to 1100°F for 5 minutes to 1 hour; three stage cycles - age at 700°F for 20 to 80 hours plus age at 900°F for 40 to 80 hours followed by flash annealing at 1050°F for 5 to 30 minutes; and an interrupted two stage cycle - age at 900°F for 66 hours, weld and re-age at 900°F for 40 to 60 hours followed by flash annealing at 1050°F to 1100°F for 30 minutes. Weldments processed in accordance with the latter cycle were characterized by very low ductility. Several of the single and multi-stage cycles showed comparable and promising results. Subsequent consistency checks on the most promising cycles, employing a greater number of specimens, proved the 900°F for 50 hours plus 1050°F for 5 minutes aging cycle to give the most consistent results. An utlimate tensile strength level of 190,000 psi, a yield strength of 170,000 psi, and an elongation of 4.5% in 2" was achieved. This cycle was selected for further evaluation.

Type of Program: Processing Development

Material Classification: Titanium

Descriptive Title: Resistance Spot Welding of B120VCA Titanium Structural Panels

Objective: To establish resistance spot welding techniques for welding B120VCA titanium in both annealed and aged conditions, and to produce small structural corrugated sandwich test panels, utilizing these techniques, for engineering evaluation.

Abstract of Results and Conclusions: Weld parameters for resistance spot welding B120VCA titanium, both in the solution treated and the aged conditions, have been established. These parameters were determined by static shear and cross tension tests at room temperatures, using MIL-W-6858A as a guide. In addition both x-ray and metallurgical examinations were made to insure optimum penetration and general weld quality. At present, elevated temperature shear, cross tension, fatigue, and joint efficiency specimens are being evaluated. Weld parameters have also been developed for roll spot welding corrugations to single skin and spot welding the second skin to the corrugated assembly utilizing intermediate copper electrodes.

Corrugated sandwich panels for compression, bend, and flexure fatigue tests are in the process of being manufactured. Corrective studies in regard to warpage of panels are being conducted in two directions. The first is a study of furnace refining techniques to correct the warpage and the second is a fundamental study of the cause of the warpage. Both studies show promise of minimizing the problem.

Type of Program: Processing Development

Material Classification: Titanium

Descriptive Title: B120VCA Titanium Brazing Program

Objective: To develop manufacturing techniques for producing brazed B120VCA titanium sandwich panels.

Abstract of Results and Conclusions: Preliminary studies have consisted of evaluating compatible brazing alloys and developing a brazing-heat treating cycle which would provide optimum mechanical properties.

The brazing alloy selected for this development program is a 95% silver - 5% aluminum alloy in .002" thick foil form. This particular filler material was chosen over the more widely used brazing alloy for titanium, i.e. 97% silver - 3% lithium, because of the improved corrosion resistance under salt spray test conditions and superior mechanical properties. Melting point and flow temperature of the brazing alloy are critical, because of the sharply sloping liquidus line for the high silver-low aluminum alloys, and require rigid control of chemical composition.

Brazing of B120VCA titanium honeycomb test panels has been accomplished to date in stainless steel retorts employing graphite tooling, argon protection, and differential pressure techniques to hold the honeycomb components in intimate contact. Successful panels can be realized providing the sandwich details are thoroughly chemically cleaned and protected from contamination prior to and during assembly. Test panels have been fabricated and are currently being evaluated at room temperature and 800°F. The specimen configurations include standard flexure fatigue, bend, and compression panels. Shear picture frame type test panels with channel edge members are presently being fabricated for room temperature and 800°F tests.

Type of Program: Processing Development

Material Classification: Nickel

Descriptive Title: Tungsten Inert Gas (TIG) Welding of Rene'41 Sheet

Objective: To investigate and evaluate the feasibility of TIG welding Rene' 41 sheet.

Abstract of Results and Conclusions: 1. Room temperature test results indicate that Rene' 41 sheet can be fusion welded by the tungsten inert gas process when welding is accomplished in the solution annealed condition (1975°F ± 25°F 1/2-hour, water quenched) and the weldment is re-solution annealed prior to final aging. The mechanical properties of weldments which have been re-solution annealed and aged after welding are somewhat lower than the parent metal.

2. Average room temperature ultimate tensile strength of welded specimens is 85% of parent material strength. Average room temperature yield strength of welded specimens is 92% of parent metal strength. Guided bend tests indicate minimum ductility in the weld and heat affected zone.

3. Optimum strengths are obtained by a flat bead with only sufficient filler rod added to prevent undercutting.

4. The importance of joint preparation prior to the welding of Rene' 41 cannot be stressed too highly. All joints must be deburred and free of all oil or grease. The edges of thin materials (e.g., .032 gage) must be polished with fine emery cloth. Heavier gages (e.g., .090 gage) may be thoroughly cleaned with a clean stainless steel wire wheel.

5. Repair welding of thin sheet metal parts (i.e., .032 and under) in areas that have been subjected to severe forming operations which cannot be properly cleaned to eliminate torn rough edges, is not recommended. When faying surfaces can be properly cleaned, the material must always be in the solution annealed condition prior to welding.

Type of Program: Processing Development

Material Classification: Nickel

Descriptive Title: Investigation of Fusion Welded Invar Foil and Sheet

Objective: To determine the feasibility of joining Invar 36 sheet and foil by the gas tungsten-arc process.

Abstract of Results and Conclusions: A program was initiated to determine the problems, if any, associated with joining Invar 36 sheet and foil, using the mechanized gas tungsten-arc process. Special emphasis was placed on the ductility of welds in subsequent forming operations.

Preliminary data on butt welded Invar 36 foil, .010" thickness, indicates a tendency for hot cracking. Welds were made by fusion of the foil edges, using no filler rod and by melting down of an upturn flange. The latter method resulted in an increase in weld width with a corresponding increase in the number of cracks. Test panels 18" x 18" fabricated by welding 6" wide strips to one another, were subjected to a spin forming operation. Premature failure of these samples was attributed to inferior weld quality.

Invar 36 sheet, .035" gage, was successfully welded both with and without the addition of filler wire. Longitudinal guided bend specimens were capable of being formed to a bend factor of 1 "T". A metallographic inspection of a typical weld structure from each gage showed distorted or elongated grains in the heavier .035" material which was in direct contrast to the crack sensitive .010" foil which exhibited undistorted equiaxed grains. The significance of this and other data to the problem of weld cracking in foil material will be evaluated in future work.

Type of Program: Processing Development

Material Classification: Nickel

Descriptive Title: Rene' 41 Brazing Program

Objective: The purpose of this program is to fabricate a Rene' 41 brazed structural component.

Abstract of Results and Conclusions: The elements that assist in imparting the unusual toughness to Rene' 41 at the higher temperatures (1400°F - 1600°F) behave in an adverse manner when it comes to brazing. At these high temperatures the aluminum and titanium present have a strong affinity for oxygen. Oxygen present in a few parts per million forms a tough oxide film which interferes with surface wetting and braze flow.

The brazing alloys being evaluated in this program are Coast 62, Nicrobraze 60W, Coast 50, and GE J8102. Brazing was initially accomplished in an argon atmosphere. The tests were repeated several times under varying conditions to observe braze flow, wetting action, base metal diffusion, fluxing results, etc.

Observations indicate that:

a) An interferring oxide film is produced at high brazing temperatures (2000°F) in an argon environment (dew point - 80°F).

b) Fluxing aids very little, if at all, because the flux breaks down at high temperature.

c) Coast alloy No. 62 exhibits a relatively high diffusibility. The effect of brazing diffusibility on Rene' 41 remains to be determined.

d) Preliminary results show that of the four alloys tested for shear values, Coast alloy No. 62 appears superior.

Further brazing will be conducted in a vacuum.

Type of Program: Processing Development

Material Classification: Molybdenum

Descriptive Title: Fabrication Program -- Molybdenum -- .5 Titanium

Objective: Development of capabilities and familiarization with manufacturing techniques required to produce advanced structures utilizing molybdenum - 1/2 titanium.

Abstract of Results and Conclusions: An intensive program is being conducted to evaluate fabricability and generate design data for molybdenum - 1/2 titanium. Extensive mechanical property testing will be utilized to determine elevated temperature tensile properties, fatigue strength, elevated temperature creep properties, effect of protective coatings, strength of mechanical joints, etc. Simulated structural components, ranging from simple to full scale complex shapes, are being fabricated and tested.

Considerable difficulty has been experienced with poor homogeneity of Mo - 1/2 Ti sheet material. Local contamination, surface impurities, and imbedded matter have caused a major portion of the material to be rejected for failing bend test requirements. Metallurgical examination has shown local surface contamination to depths up to .004" in some instances. This problem has been resolved by prescribing proper grinding and/or pickling operations for as-rolled sheets.

Type of Program: Processing Development

Material Classification: Ceramics

Descriptive Title: Ceramics for Aircraft Tooling

Objective: To develop processes for the manufacture of ceramic tools capable of forming super alloys at temperatures up to 2000°F.

Abstract of Results and Conclusions: Various ceramic materials coupled with specific designs are being evaluated for suitability as high temperature tooling materials. The completed tool will be analyzed for thermal shock, linear expansion coefficient, tool life, and cost.

To date, a fused silica mated die has been developed for forming Inconel X and Rene'41 at 1900°F. The die life and thermal shock properties were satisfactory for the intended purpose. Thermal shock was measured by cycling the die from room temperature to 2000°F. Die life was determined by fabricating over 200 parts without any visual failure or damage to the tool. Linear expansion coefficients were roughly determined and more exact values using a dilatometer will be established.

From these initial studies and estimated costs it appears that fused silica tooling can be successfully employed for hot forming super alloys and refractory metals at temperatures above 1500°F.

Type of Program: Processing Development

Material Classification: Ceramics

Descriptive Title: Ultrasonic Machining of Brittle Materials

Objective: To investigate the parameters and techniques involved in ultrasonic machining.

Abstract of Results and Conclusions: Ultrasonic impact grinding investigations have been conducted with a wide range of brittle materials including alumina, vitreous ceramic, KT silicon carbide, pyrex, and ceramic coated tungsten and molybdenum. Tool wear rates ranging from .008 inches/inch for glass to 2 inches/inch for tungsten (inches tool-wear/inch cavity depth) were determined. Investigation using a deflocculent mixed with the abrasive slurry to keep the abrasive in suspension resulted in increased drilling times and, hence, were discontinued. An efficient interchangeable tool holder using mild steel tools was developed to facilitate tool changing. The use of plaster imbedent techniques to alleviate breakout were investigated and developed to increase drilling reliability. Additional investigations are being undertaken to determine hole taper, drilling rates, and methods for feeding the slurry into the cavity.

Type of Program: Processing Development

Material Classification: Coatings

Descriptive Title: Protective Coatings for Refractory Metals

Objective: To develop processing techniques for oxidation resistant coatings for refractory metals, particularly molybdenum and columbium alloys.

Abstract of Results and Conclusions: The processes being studied are spraying (flame), liquid phase diffusion, plating, electrophoresis, vapor deposition, and pack cementation. Coating materials to be employed will be LB-1, LB-2 (General Electric), chromium, chromium-nickel, gold, rhodium, disilicides of molybdenum and tungsten, and packs such as CR-Ti-Si, and CR-Al-Si.

Processes studied to date are liquid-phase diffusion of LB-2 on columbium, electrophoresis of molybdenum disilicide on molybdenum - 1/2 titanium, and various platings for protection of columbium.

Photomicrographs and static oxidation resistance tests have been performed.

The preliminary investigation as described above has shown that the processes and coating materials presently available are not satisfactorily developed for use above temperatures of 2500°F.

This program will be continued and modified to accommodate any new protective materials that show promise.

Type of Program: Processing Development

Material Classification: Ceramics

Descriptive Title: Sprayed Ceramic Coatings

Objective: To determine the process variables involved in flame sprayed ceramics.

Abstract of Results and Conclusions: A number of ceramic materials, such as alumina, chrome oxide, zirconia, and zircon are being flame sprayed (oxy-acetylene) for various coating applications. Spraying techniques will ultimately be determined for these coatings on various types of substrates, both metallic and non-metallic. Substrate preparation, optimum coating thickness, material feed rate, and pressure settings have been determined for alumina coatings on steel and copper. These coatings have been used for erosion and emissivity control. Additional work is being conducted on alumina coatings on aluminum.

Type of Program: Testing Techniques

Material Classification: Fatigue

Descriptive Title: Feasibility Study on the Development of a Pre-Crack Fatigue Damage Indicator

Objective: The object is to develop techniques to produce a gage which will provide indication of the percentage of total fatigue life absorbed in structural elements during service loadings. (Contract AF33(616)-7103).

Abstract of Results and Conclusions: All efforts to date have been concentrated on producing a fatigue damage indicator which would be suitable for indication of percentage fatigue life consumed in 7075-T6 structural elements. Several different approaches, all using thin wire, have been investigated. The approaches investigated included fracture of very fine wires (.0005" - .0025" diameter) induced by slip bands in the fatigue damaged structure. Five different wire materials were evaluated in test from which platinum was selected for further work. Detailed experimental work with the very fine platinum wires showed high scatter in their fracture life on fatiguing aluminum specimens. The next approach employed thin heat treated 2024 and 7075 wires (.003" - .010" dia.). Pre-fatiguing of this wire before installation on test specimen was necessary to cause its failure to preceed that of the specimen. The results showed too much scatter to allow measurement of fatigue damage in the specimen by fracture of the wires. Etching, indenting, and annealing of the aluminum wires were then investigated as to their effects on fatigue life. Annealing of the wires was found to result in minimum fatigue scatter. However, the scatter which does exist necessitates a statistical evaluation of the ratio between the number of broken to unbroken wires in determining fatigue damage. Efforts are now being made to develop a multiple wire indicator.

Type of Program: Testing Techniques

Material Classification: Corrosion

Descriptive Title: Accelerated Corrosion Test Method,7079-T6 Aluminum Alloy Parts Suspected of Having a Significant Residual Stress Level

Objective: To evolve a test procedure or method for determining, in a relatively short time (one - two weeks max), a particular configuration's susceptibility to stress corrosion due to residual stresses, obviating the need for tedious residual stress determinations by mechanical methods.

Abstract of Results and Conclusions: The procedure included finding a solution aggressive enough to cause failure within the designated time period at a stress level equal to or below what is normally considered to be the safe stress level as determined by standard accelerated corrosion testing methods (normally 3 1/2% Na Cl alternate immersion).

Solutions evaluated include:

1) An aqueous mixture of chromic acid, sodium chloride, potassium dichromate, and aerosol.
2) An aqueous solution of sodium chloride, hydrogen peroxide, and aerosol.
3) Aqueous solution of mercuric chloride.
4) Aqueous boiling sodium chloride solution.

The mercuric chloride solution satisfied the conditions imposed for the specific part under consideration. Very rapid failure was induced at a satisfactory stress level with excellent reproducibility of results.

Data obtained in this study will appear in ESRT 20, copies of which will be forwarded to the Air Force on or about November 1, 1961.

Type of Program: Testing Technique

Material Classification: Strain Measurement

Descriptive Title: Thermal Strain Investigation

Objective: To develop and provide instrumentation procedures, together with the methods of data analysis, which would be applicable to either flight or laboratory structure testing and which when applied would result in a satisfactory description of the loads and strains (or stresses) in a structure subjected simultaneously to external mechanical loads and the effects of a thermal environment. Thus, the load criteria and method of analysis used in the design stage are checked simultaneously. (Contract No. AF33(616)-6869).

Abstract of Results and Conclusions: The work has been formally reported in WADD TR-61-92 (RAC Ref. No. ESRD 4). The development of a Technique for the Determination and Description of Loads and Strains in Hot Structures (Makemson and Switsky). The technique developed offers a combined experimental and analytical technique supported by statistical methods for the in-flight determination of loads and strains in structures subject to a thermal environment. The final laboratory demonstrations illustrated that flight loads could be accurately measured and that when the required analysis was programmed for machine computation, all required information could be available in final form within minutes of test conclusion. A Republic proposal (ESP. 18), which suggests a program which would further refine and develop this technique, has been submitted to the contractual agency which sponsored the original work, and is currently under consideration.